DEFINITION

Hyperbaric oxygen (HBO) therapy is a medical treatment for specifically indicated conditions in which a patient breathes 100 percent oxygen in a pressurized chamber at elevated pressures.

Although HBO therapy is vital in the resolution of certain critical care situations such as carbon monoxide poisoning, gas gangrene, diving or surgically induced gas embolism, and decompression sickness, it also is considered an important adjunctive therapy for a growing number of chronic conditions.

Hyperbaric oxygen therapy performed by the Hyperbaric Medicine Unit of Inova Mount Vernon Hospital is conducted only within and according to the strict regimens established by the Hyperbaric Oxygen Committee of the Undersea and Hyperbaric Medical Society (HOC/UHMS).

For more information, call the Inova Mount Vernon Hospital Hyperbaric Oxygen Therapy Unit at 703-664-7218.
**Physician’s Reference**

Information in this booklet will provide the treating physician with an overview of conditions and diseases proven responsive to HBO therapy. Inova Mount Vernon Hospital will treat those patients diagnosed under the “currently accepted” category. Although HBO was developed to treat victims of diving accidents, it is proving effective against a growing number of disorders.

**Currently Accepted Diseases Treated**

- radiation necrosis
- decompression sickness
- carbon monoxide poisoning
- gas embolism
- gas gangrene
- refractory osteomyelitis
- soft tissue infections with tissue necrosis
- crush injury
- compromised skin grafts or flaps and enhancement of healing in selected problem wounds
- cyanide poisoning
- thermal burns
- refractory diabetic leg/foot ulcers
- certain chronic refractory diabetic wounds, approved by Medicare as of April 1, 2003.

Other cases may be considered on an individual basis or as part of an established research protocol.

The HOC/UHMS constantly reviews results of submitted experimental data and may from time to time upgrade the status of treatable disorders from investigational to accepted. Information on these changes and adjustments will be passed along as received.

**Techniques and Mechanism of Action**

Arterial pO2 values of 1100-1900 mmHg are achieved by having the patient breathe 100 percent oxygen at chamber pressures of 2.0 to 3.0 times sea level atmospheric pressure. The resulting increase in oxygen diffusion distance from functioning capillaries in a hypoperfused wound results in normalization of oxygen tension. This has been confirmed by oxygen electrode measurements.

During hyperbaric treatments, elevation of tissue pO2 results in:

- Fibroblast division and collagen production to provide support for capillary proliferation. Thus, one use is to help prepare a rich vascular bed for skin or bone grafting in venous stasis ulcers, certain diabetic ulcers with reasonable regional perfusion, infected open amputation stumps or osteomyelitis.
- Enhanced leukocyte killing of bacteria, an oxygen dependent process.
- Cessation of toxin production by the causative clostridial organisms in gas gangrene.
- Rapid dissociation of carbon monoxide from hemoglobin and CNS cytochrome oxidase A3 and physically dissolved oxygen available to neural tissue.
- Elimination of intravascular and tissue gas bubbles that trigger coagulopathy and other mechanisms in the complex diving disorder decompression sickness.
- Restoration of CNS perfusion by compression and dissolution of intravascular gas emboli in pulmonary overpressure diving accidents or iatrogenic intravascular gas embolism.
- Vasoconstriction resulting in a 20 percent reduction in edema formation without tissue hypoxia.
CONSULTATION PROCEDURE

Patients are seen in consultation upon referral from their attending physician or surgeon.

It is emphasized that HBO therapy is adjunctive to continuing medical and surgical care. Referred patients will remain under the primary care of the attending physician or surgeon.

PRECAUTIONS

The therapy itself (i.e., pure oxygen inhalation at higher than normal atmospheric pressure) is totally painless. It is possible, however, that a patient may experience pressure within the ears during decompression. The attending staff will assist the patient in adjusting to these conditions. However, patients with colds, or cold symptoms, should not undergo therapy until the condition abates.

Smoking and hyperbaric oxygen are clinically incompatible. All patients are urged to stop smoking. In some instances, smoking must be completely relinquished by the patient for the entire period of therapy treatments. If the patient cannot completely abstain from smoking, therapy may have to be discontinued.

The treatment protocols have all be carefully designed to minimize oxygen toxicity.

Certain drugs and other medications may produce unwanted side effects and should be avoided. The HBO therapy physician will provide specific information on all drugs and medications under question.

Since HBO therapy is a method of delivering oxygen in a highly efficacious manner, the normal precautions associated with oxygen therapy should be heeded with even greater concern. Rigorous safeguards are followed to prevent fire hazards. Patients are encouraged to refrain from alcohol (ETOH) use as dehydration can increase risk of O2 toxicity and ETOH causes dehydration.

THE CHAMBERS

Patients are treated in two monoplace HBO chambers. The clear acrylic units allow full visual contact and two-way communication by telephone with the patient.

This includes cardiac monitoring, arterial pressure monitoring, and temperature and respiration monitoring. The chambers allow us to administer multiple IVs so that we can deliver needed fluid, blood and medications. For prolonged treatments such as decompression sickness, we are equipped with an air mask for intermittent air breathing to prevent oxygen toxicity.

Patients may listen to a radio and tapes, watch television, or watch a movie.
**Radiation Necrosis, Osteoradionecrosis, Soft Tissue Radiation Necrosis, Caries in Radiated Jaw and Radiation Cystitis**

**QUALIFICATIONS**

The patient must be treated in close coordination with the appropriate surgeon. HBO therapy must be part of an overall plan in which debridement, resection of involved bone, bone grafting, myocutaneous flap reconstruction and specific antibiotic therapy are included as indicated. Pre- and postoperative hyperbaric oxygen is indicated to achieve resolution. Peer review is required after 60 treatments.

**RATIONALE**

At some time after irradiation therapy for malignancies, a small percentage of patients develop disabling painful and potentially fatal tissue breakdown. The basic pathology of this process is progressive proliferative endarteritis with resultant tissue ischemia. In soft tissue radiation necrosis, newer reconstruction techniques often allow total excision of the involved area with repair by vessel-bearing myocutaneous flaps in which case hyperbaric oxygen is not usually needed. In some, however, particularly the mandible and maxilla, total surgical ablation would be disfiguring and reconstruction impossible. HBO therapy for radiation damaged tissue was introduced in 1973 by Greenwood and Gilchrist, and Mainous, Boyne and Hart. With daily elevation of partially ischemic hypoxic bone and soft tissue oxygen tension near regions of functioning capillaries, fibroblastic proliferation, collagen synthesis, and capillary angiogenesis proceed.

Hypoxic leukocytes’ impaired bacterial killing ability is restored to normal with elevation of bone oxygen tension to or above normal. Preoperative hyperbaric oxygen thus prepares a vascular, non-infected wound to enable the surgeon to successfully debride and later reconstruct such wounds. Unplanned but required surgery in previously irradiated tissue is fraught with a known high incidence of complications. Adjunctive HBO therapy has changed this picture.

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**PSYCHOLOGICAL CONSIDERATIONS**

While the physical side effects associated with HBO therapy are explicit and manageable, the therapy environment may present psychological reactions that must be understood and considered.

The patient will be confined in a relatively restricted vessel for approximately two hours, while having full visual and audio contact with the immediate external environment, and constant attendance by our professional staff.

The patient cannot physically vacate the pressurized chamber at will. Thus, the treating physician will evaluate the patient’s potential for claustrophobic response. In an emergency situation, it is possible to depressurize a patient rapidly.

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**OUTPATIENT AND INPATIENT CARE**

HBO therapy may be given on an outpatient or inpatient basis depending on the patient’s needs. The Hyperbaric Medicine Unit is available 24 hours a day, seven days a week.
Carbon Monoxide Poisoning, Acute

QUALIFICATIONS

Treatment must be initiated during the acute episode.

RATIONALE

Oxygen inhalation to hasten dissociation of carbon monoxide from hemoglobin, as well as to provide tissue oxygenation is the one time-honored and fully accepted therapy and, as expected, has yielded vastly improved clinical results.

If it is available, hyperbaric oxygen is mandatory for CO poisoned patients who do not recover fully at once with sea level oxygen breathing. Carboxyhemoglobin dissociation is further hastened over that possible with one atmosphere (sea level) oxygen, physically dissolved oxygen in plasma is delivered to hypoxic tissues and CO bound to cytochrome oxidase in tissue is more rapidly eliminated. Over 780 cases reported in the literature and additional hundreds of as yet unreported but well-documented cases treated by HOC/UHMS members all have yielded the same positive results – rapid improvement of symptoms and signs and probable reduction of the incidence of late sequelae.

A caution is that treatment with hyperbaric oxygen must be predicated more on the history and clinical picture than on carboxyhemoglobin levels to try to minimize the late neurologic deficits.

COST IMPACT

Cost of hyperbaric oxygen in this condition is modest since it is the primary mode of therapy and used only acutely in cases that do not respond at once to sea level oxygen inhalation. Our opinion now holds that more than one treatment is often indicated in the hours or days immediately following acute poisoning, but this should not exceed seven days without peer review. Prevention of late neurologic deficits can represent significant savings to the health care system.

Decompression Sickness

QUALIFICATIONS

Cases treated immediately are usually resolved with only one treatment. Attention must be directed to cases with delay reaching the chamber or very severe cases, which could require prolonged (several days) chamber treatment and/or repeat daily hyperbaric oxygen treatments for best possible result. In view of modern hyperbaric medicine, these measures are fully accepted by the committee.

RATIONALE

This disorder is treatable only in the recompression or hyperbaric chamber. Treatment protocols based on over 100 years experience are used and need no further discussion.

COST IMPACT

Only those people exposed to increased ambient pressure or who suffer decompression sickness at altitude are affected. Therefore, the number of cases will be small.

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Osteoradionecrosis is an extremely painful and disabling condition. It is potentially fatal if major vessels are eroded. Newer irradiation techniques should produce fewer cases than in the past. Numbers of patients should not be large but, for those afflicted, hyperbaric oxygen-enabled reconstruction can interrupt a long and expensive clinical course in about 85 percent of the cases treated.

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Gas Embolism, Acute

QUALIFICATIONS

Recompression in a hyperbaric chamber is the treatment of choice after gas emboli are introduced into the arterial or venous system. This includes emboli arising from diving, surgery, diagnostic procedures, gynecologic manipulations or renal dialysis. In heart surgery, Stoney, et al, found 429 cases over a five-year period in 375,000 perfusions. Treatment must be initiated during the acute period, but while results are better if recompression is within minutes after the incident, cases that recovered with treatment hours later made a trial of recompression mandatory even in late cases. Diving medicine physicians now recognize that repeat hyperbaric oxygen treatments may hasten resolution of residual signs in some cases. Peer review is required after 10-14 treatments.

RATIONALE

Intravascular gas emboli can be forced into solution when chamber pressure is elevated. In addition, an environment of 100 percent oxygen results in dissolution of bubbles by gas exchange. In the central nervous system, those cells that are viable, but cannot function in a low flow state can be expected to resume function when flow is increased. Irreversibly damaged neural elements will result in permanent damage. Observations of further improvement during repeat hyperbaric oxygen treatments have led to acceptance of this practice although the exact mechanism of action is not clear.

COST IMPACT

The treatment of choice for gas embolism from any cause is recompression therapy. Prevention of permanent neurologic and myocardial ischemic sequelae will represent vast savings to the health care system.

Gas Gangrene

QUALIFICATIONS

HBO therapy is to be used for clostridial myonecrosis or spreading clostridial cellulitis with systemic toxicity – or a presumptive diagnosis of either.

HBO therapy is to be used as an adjunct to surgery and antibiotic treatment.

RATIONALE

Gas gangrene is caused by any of six pathogenic clostridial organisms, which are able to grow and produce tissue necrotizing toxin in humans. Ninety percent of cases are caused by clostridium perfringens. Clostridium perfringens grows rapidly in oxygen tensions below 300 mmHg. Restricted growth is seen in oxygen tensions of 70 mmHg, and oxygen tensions of 250 mmHg stop alphatoxin production. It is important hyperbaric oxygen be started early and continued until progress of the anaerobic infection is clearly stopped. A minimum of five HBO treatments is recommended. Hyperbaric oxygen must be started on the basis of surgical impression and demonstration of clostridial organisms on gram-stained smear of involved tissue. By elevation of wound oxygen tension in the region of functioning capillaries in the infected wound, further toxin production is stopped and necrotic tissue can be debrided, salvaging more viable tissue than otherwise possible. Initially, fasciotomy when indicated should precede hyperbaric oxygen treatment and, at a later stage, debridement of necrotic tissue can be performed between hyperbaric oxygen treatments. The need for emergency life-saving ablative surgery is obviated as hyperbaric oxygen stops further progression.

COST IMPACT

Reduction of morbidity and prevention of amputation, or at least lowering the level of amputation required in limb gas gangrene, justify the costs. Treatment extending beyond a few days is seldom if ever required.
Osteomyelitis, Refractory

QUALIFICATIONS

Cases accepted for adjunctive hyperbaric oxygen must be judged to be refractory to adequate surgery and specific parenteral antibiotic treatment. While hyperbaric oxygen should improve results in acute osteomyelitis, it is considered too expensive, except in critical sites such as skull, vertebra, hand, elbow or other life-or-function threatening acute cases that have not responded at once to surgery and antibiotics. Judgement in declaring a given case refractory or critical must be jointly made by the surgeon and hyperbaric medicine specialists. Peer review is required after 60 treatments.

RATIONALE

Following initial anecdotal case reports of successful use of adjunctive hyperbaric oxygen in very difficult cases during the 1960’s, controlled animal studies clearly demonstrated benefit using hyperbaric oxygen. Studies to determine mechanism of action include demonstration of hypoxia in infected bone with elevation to normal or above normal bone pO2 when animals breathe oxygen in the hyperbaric chamber. Periodic elevation of bone pO2 from hypoxic levels to normal or above normal promotes fibroblastic division and collagen production and capillary angiogenesis as structural support is provided for budding capillaries. Hypoxic polymorphonuclear leukocytes killing of S. aureus is returned to normal when bone oxygen tension is raised.

HBO therapy must be used as an adjunct to debridement, wound care, specific bone culture dictated parenteral antibiotic administration at synergistic levels with bone graft, vessel-bearing flaps and, in the case of infected non-union, electrical stimulation as indicated. Besides the benefit of HBO therapy in enhancement of success of these measures because of the mechanisms described above, there is evidence hyperbaric oxygen may enhance osteogenesis. The growing awareness of the importance of anaerobic bacteria involved in chronic osteomyelitis is another obvious indication for hyperbaric oxygen.

COST IMPACT

When used within the above qualifications and discontinuing as soon as it appears success will not be possible, hyperbaric oxygen is not only clinically effective but also quite cost effective. Sixty to 85 percent of cases that had failed to respond after years of costly repeated surgery and antibiotic care have been arrested successfully after intensive surgical-antibiotic approach using adjunctive hyperbaric oxygen. In other cases, especially about the skull or extensive osteomyelitis, it has truly proved lifesaving. Peer review is required after 60 treatments.

Soft Tissue Infections with Tissue Necrosis

Soft tissue infections due to mixed aerobic and anaerobic organisms with tissue necrosis and refractory bacteroides infections, including necrotizing fascitis, synergistic necrotizing cellulitis, progressive dermal gangrene, severe cases of anaerobic streptococcal myositis, and crepitant anaerobic cellulitis have benefited from HBO therapy.

QUALIFICATIONS

To be used as an adjunct to surgical and antibiotic treatment.

RATIONALE

Organisms other than Clostridia can cause gangrenous infections. In these synergistic infections, one characteristic is the presence of bacterial species with differing oxygen requirements. Favorable clinical reports indicate an adjunctive role for hyperbaric oxygen in these difficult and often life-threatening infections. It is emphasized that primary management remains adequate surgical debridement and antibiotics, but hyperbaric oxygen is a useful adjunct in difficult cases, such as fourier’s gangrene.

The oxygen tension in infected soft tissue is low. Hyperbaric oxygen increases the tissue oxygen tension in infected tissue to levels where anaerobic organisms are inhibited or killed. The increase in tissue tension also allows the host defense cells – polymorphonuclear leukocytes (PMN’s) – to optimally kill aerobic and anaerobic organisms. Clinical studies have demonstrated the beneficial effect of adjunctive HBO in mixed aerobic/anaerobic soft tissue infections. Hyperbaric oxygen must be used only as an adjunct to accepted surgical care and antibiotic treatment.

COST IMPACT

The life-, limb-, and tissue-threatening aspects of those disorders justify the costs involved. Additionally, treatment times would not be expected to extend over three to seven days.
Crush Injury with Acute Traumatic Ischemia

QUALIFICATIONS

This must be used as an adjunct to standard surgical treatment including vascular repair as indicated. Must be initiated within 48 hours of injury.

RATIONALE

An excellent review of this subject with 48 references was published in 1981 by Strauss. He emphasized the importance of the level of arterial damage. Even high arterial pO2 achievable with hyperbaric oxygen will not be of value in cases of large vessel occlusion without adequate collateral circulation, but may be of considerable value in supporting partially ischemic tissue in wound with areas of occlusion in smaller peripheral vessels or with marginal collateral circulation. Guyton points out that “oxygen transport to the tissues is the most nearly flow-limited of all the common physiologically important substances transported by the blood.” With oxygen inhalation at two ATA or greater, plasma dissolved oxygen is delivered to marginally perfused tissues in the wound to support tissue viability. HBO therapy must be used in close coordination with surgical care.

There is further rationale for value as intermittent elevation of wound oxygen tension improves leukocyte bacterial killing. It is preferable that these wounds are treated within eight hours of occurrence, but benefit has been reported in cases started as late as 48 hours after injury.

COST IMPACT

Considerable decrease in morbidity and resultant hospitalization is anticipated with a cost savings.

Compromised Skin Grafts or Flaps and Enhancement of Healing in Selected Problem Wounds

QUALIFICATIONS

HBO therapy is not indicated for normal skin grafts or flaps. It can be used for preparing a granulating base for skin grafting where viability of graft or flap is compromised or uncertain, or where previous grafts have failed. Preoperative hyperbaric oxygen is effective by promoting capillary proliferation to prepare for grafting in poorly granulating wounds. Regarding specific partially ischemic wounds of soft tissue, current experience from centers of HOC/UHMS members, being prepared for publication, yields some important recommendations.

1 Diabetic Wounds: The major question is that of the status of perfusion in the wound area. There exists an infinite variety of states, ranging from nearly total large vessel occlusion with little wound perfusion to those with small vessel involvement and adequate perfusion for the wound to heal slowly but without hyperbaric oxygen. Obviously, in both states, hyperbaric oxygen is not recommended. Between these extremes are marginal wounds that may respond well to hyperbaric oxygen. Regular active daily debridement is required as hyperbaric oxygen progresses. Certain refractory diabetic leg/foot ulcers have recently been approved by Medicare.

2 Venous Stasis Ulcers: In general, hyperbaric oxygen is not approved for such wounds because venous surgery, local wound care, leg elevation, and counterpressure support and skin grafting as indicated will succeed. Only occasionally with failure of these procedures is hyperbaric oxygen warranted.

3 Decubitus Ulcers: In general, hyperbaric oxygen is not approved because good nursing care and skin flap as indicated are successful. Occasionally hyperbaric oxygen is warranted in a case with underlying osteomyelitis, in case of a compromised skin flap or an infected wound to help control infection and promote capillary angiogenesis to prepare for reconstructive surgery.

4 Arterial Insufficiency Ulcers: In general, hyperbaric oxygen is not approved because most cases that can be resolved need surgical revascularization. In occasional cases, the skin wound persists after bypass surgery has restored large vessel function and a short course of hyperbaric oxygen will achieve healing or prepare a healthy vascular bed for skin grafting.

Peer review is required after 20 treatments when preparing a site for grafting and after 10 treatments post grafting.
RATIONALE

While hyperbaric oxygen is not recommended for normal skin grafts and flaps, Gruber, et al., showed that in skin flaps in rats, hyperbaric oxygen at 3 ATA raised mean tissue pO2 tension to 600 mmHg, while 100 percent oxygen at sea level did not raise mean flap pO2. With locally interrupted vascularity, there was impaired healing in controls, while healing in the hyperbaric group approached normal.

COST IMPACT

If hyperbaric oxygenation is used very judiciously in selected cases, there is a savings in rehospitalization and reoperation.

Cyanide Poisoning, Acute

QUALIFICATIONS

To be used as an adjunct to standard medical treatment. Despite the scarcity of clinical experience, this entity is classed as accepted because of the powerful physiological rationale, controlled animal study by Skene and the high mortality rate in this rare poisoning.

RATIONALE

There is animal evidence to support the use of hyperbaric oxygen in cyanide poisoning and recent research has shown that the mode of action may be similar to that in carbon monoxide poisoning, as in both instances cytochrome A3 oxidase is affected. Human experience is rare in this condition but hyperbaric treatment has been efficacious when used. Some conflicting clinical data will be forthcoming in the literature, Litovitz, et al., reported questionable value of HBO in one case. Yet, a telephone survey of committee members reveals that of nine unpublished cyanide poisoned patients treated in their chambers, the only death was a case referred too late after the patient was moribund. The other eight were judged to respond well to HBO therapy.

COST IMPACT

Due to the rarity of this condition, very few claims are anticipated.

Thermal Burns

RATIONALE

The adjunctive use of HBO therapy in thermal burn treatment was recently upgraded to an accepted indication by the Undersea and Hyperbaric Medical Society. The rationale for treatment of the burn wound is based on the complex and dynamic pathophysiologic process of the wound.

The burn wound is characterized by a zone of coagulation, surrounded by a region of stasis, bounded by an area of hyperemia. An intense inflammatory reaction, leading to edema formation, increased microvascular permeability and sluggish blood flow results in thrombosis, ischemia and advancing necrosis. This progressive ischemia may increase over the first 48 hours post injury. There is increased susceptibility to infection, prolonged healing and excessive scarring.

Because the burn wound is hypoxic, the ongoing tissue damage extends its margins in the days following injury. Regeneration and healing cannot start until an equilibrium is reached. This prolongation of the healing process can lead to excessive scarring.

HBO is used to assist with edema reduction and salvage of marginal tissue if used in the first eight hours. There has been observed reduction in fluid requirements, a reduction in healing time and improvement in mortality rate in a double blind study done in California.

For information about the Hyperbaric Oxygen Therapy program at Inova Mount Vernon Hospital, please visit our Web site at www.inova.org, or call us at 703-664-7218.
Inova Health System is a not-for-profit health care system based in Northern Virginia that consists of hospitals and other health services including emergency and urgent care centers, home care, nursing homes, mental health and blood donor services, and wellness classes. Governed by a voluntary board of community members, Inova's mission is to provide quality care and improve the health of the diverse communities we serve.

www.inova.org

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